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(54) **GAS EXPANDER**

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See application file for complete search history.

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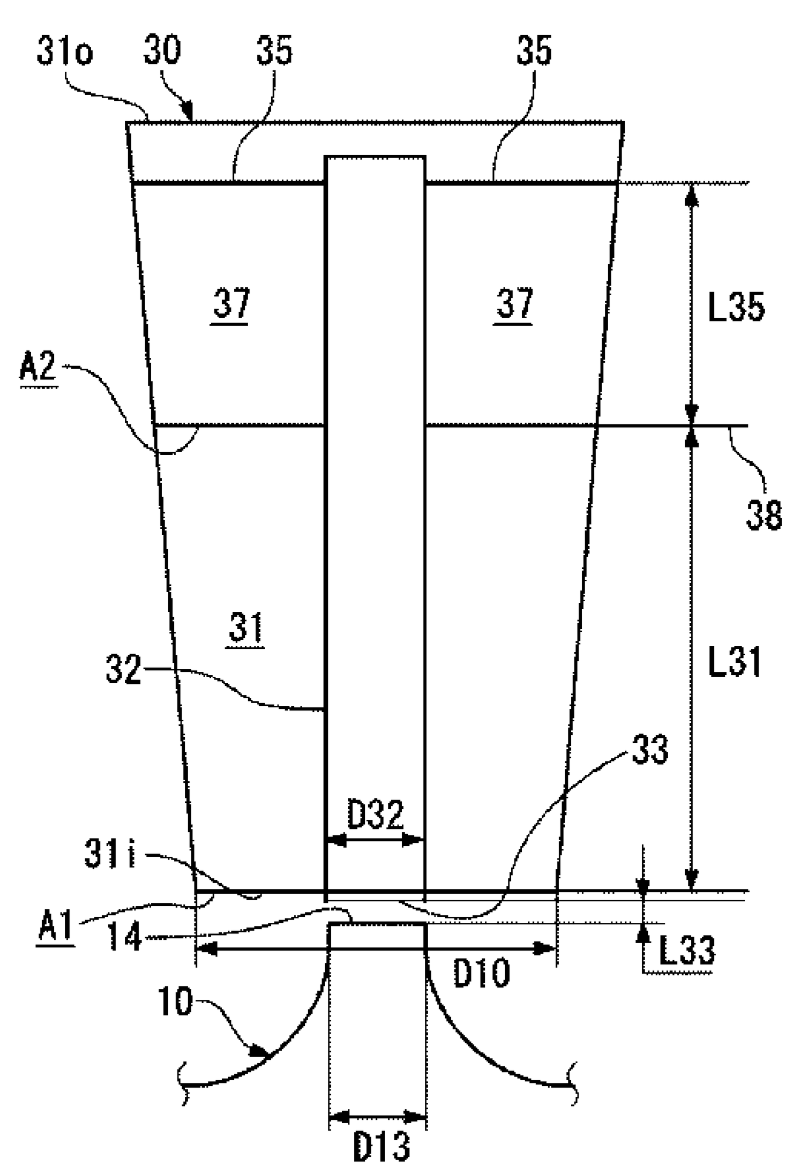
(57) **ABSTRACT**

A gas expander includes: a casing where a swirl chamber for a gas to be expanded is formed; a turbine wheel that is housed in the casing and rotationally driven by the expanded gas; a diffuser that is mounted to the casing in a direction of a rotating shaft of the turbine wheel and includes a flow path for the expanded gas to flow in the direction of the rotating shaft; a swirl stopper that is disposed in the diffuser, faces a downstream front end surface of a boss of the turbine wheel that faces the flow path, and includes a closed swirl stopping surface that is disposed to face the downstream front end surface of the boss with a gap between the closed swirl stopping surface and the downstream front end surface; and a swirl preventing plate that circumferentially partition the flow path in the diffuser.

16 Claims, 5 Drawing Sheets



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F01D 25/30	(2006.01)
F02C 1/04	(2006.01)
F02K 1/40	(2006.01)
F01D 1/08	(2006.01)

(52) **U.S. Cl.**

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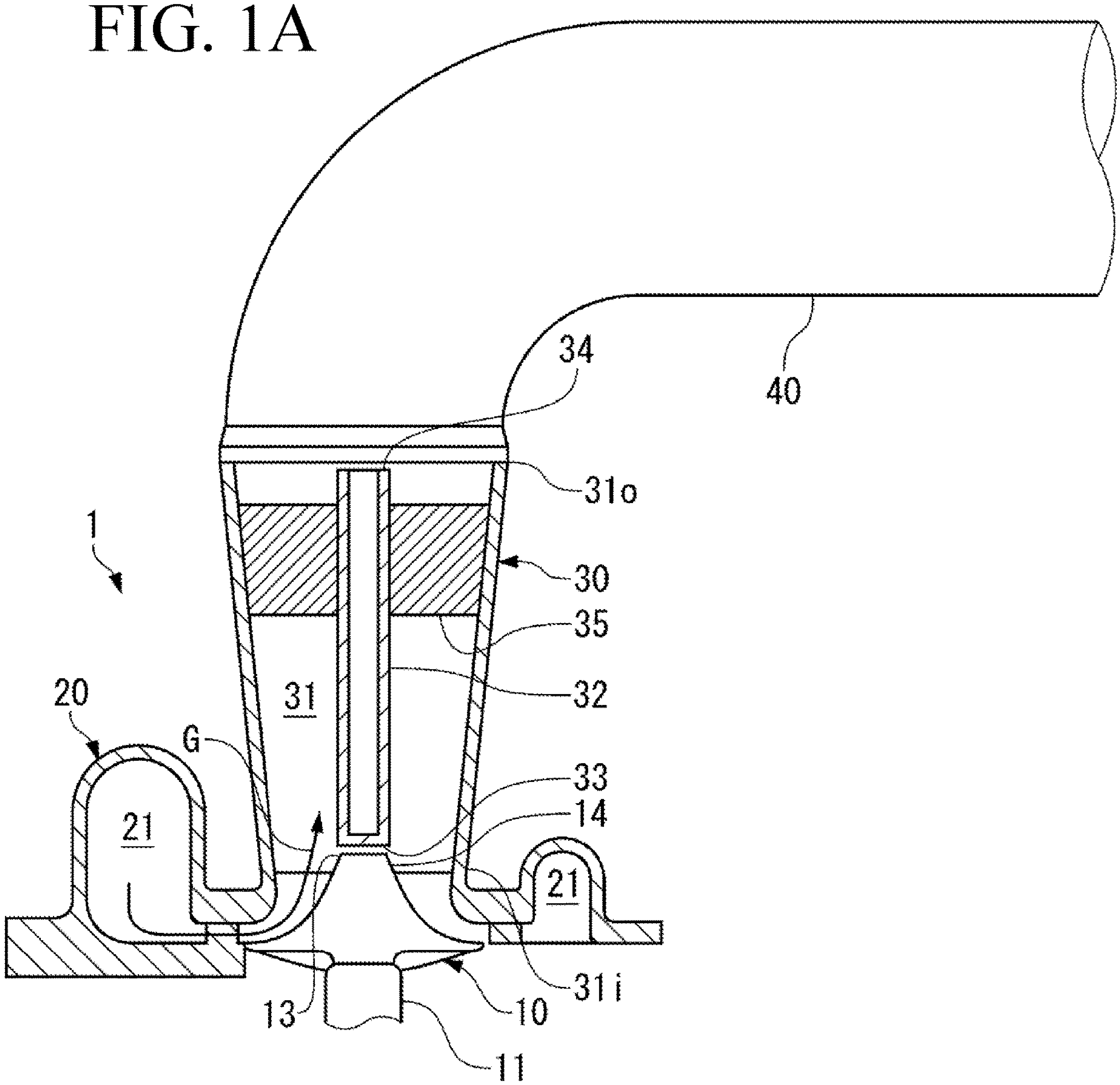
FIG. 1A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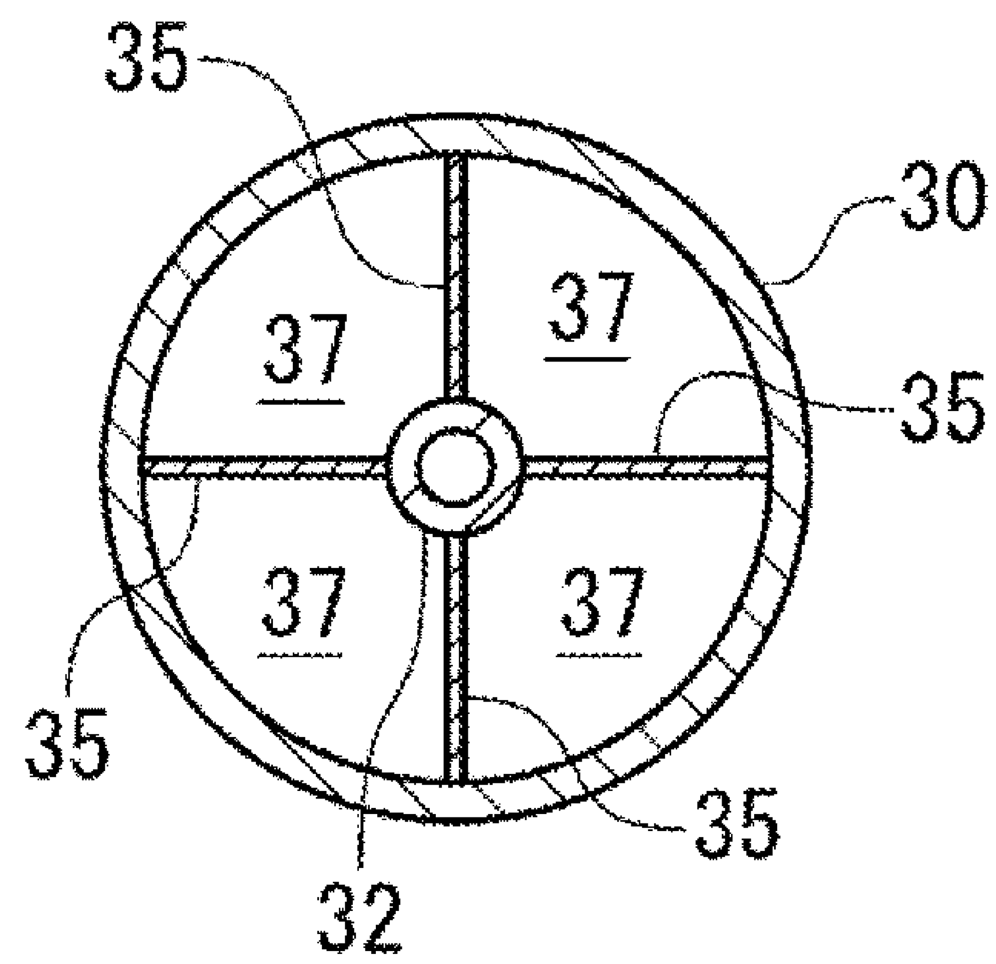
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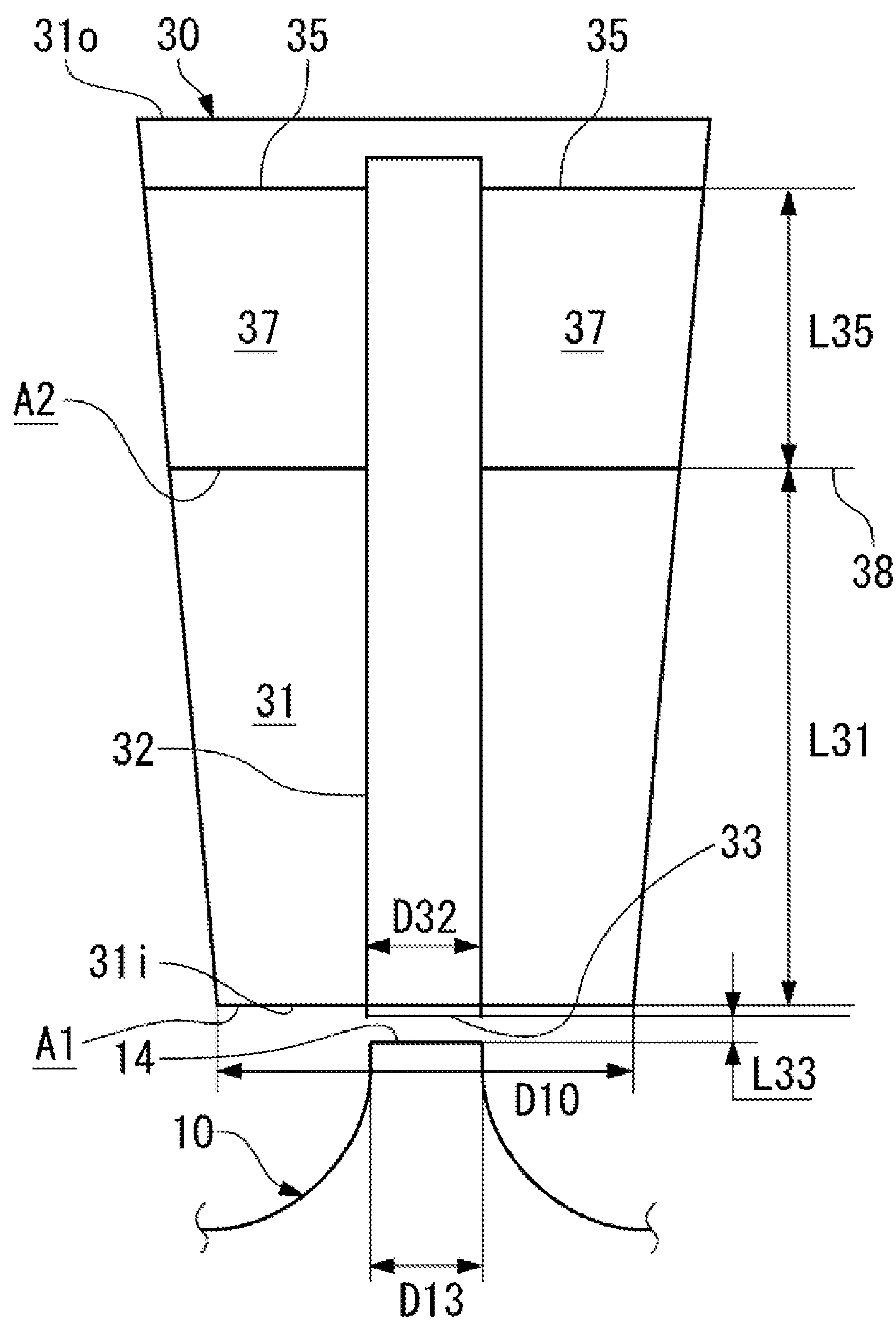
FIG. 1B

FIG. 2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D10
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FIG. 3A

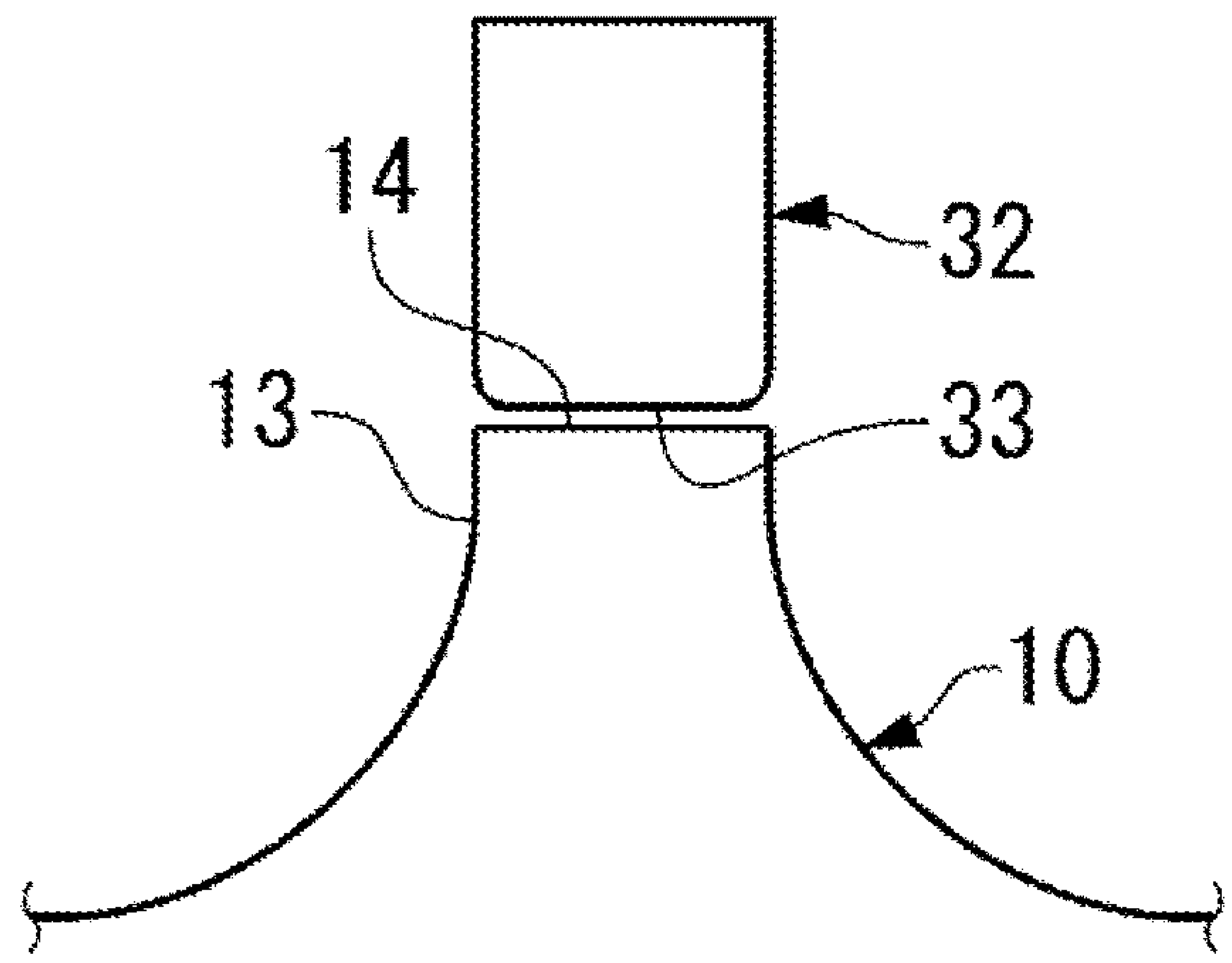


FIG. 3B

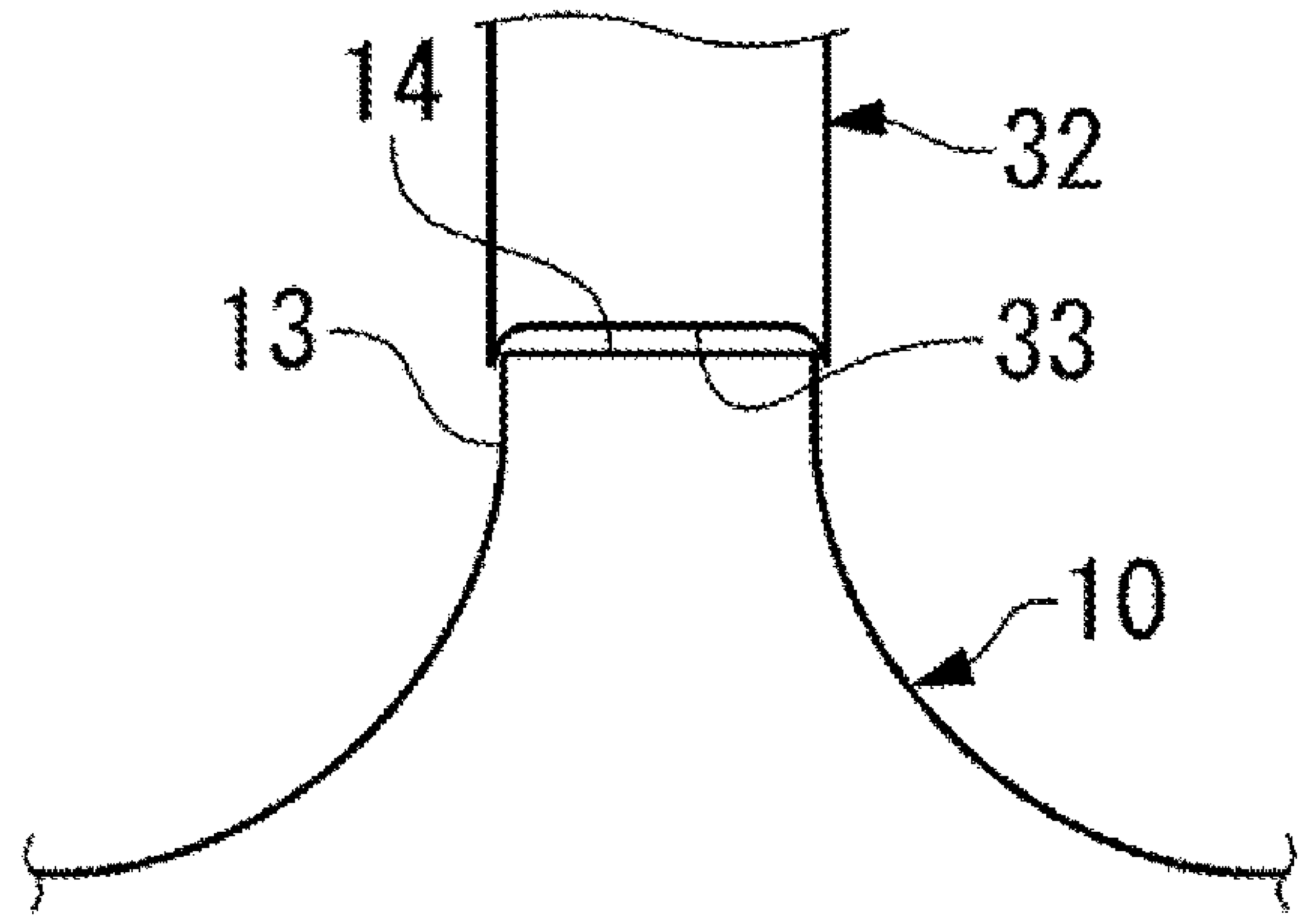


FIG. 3C

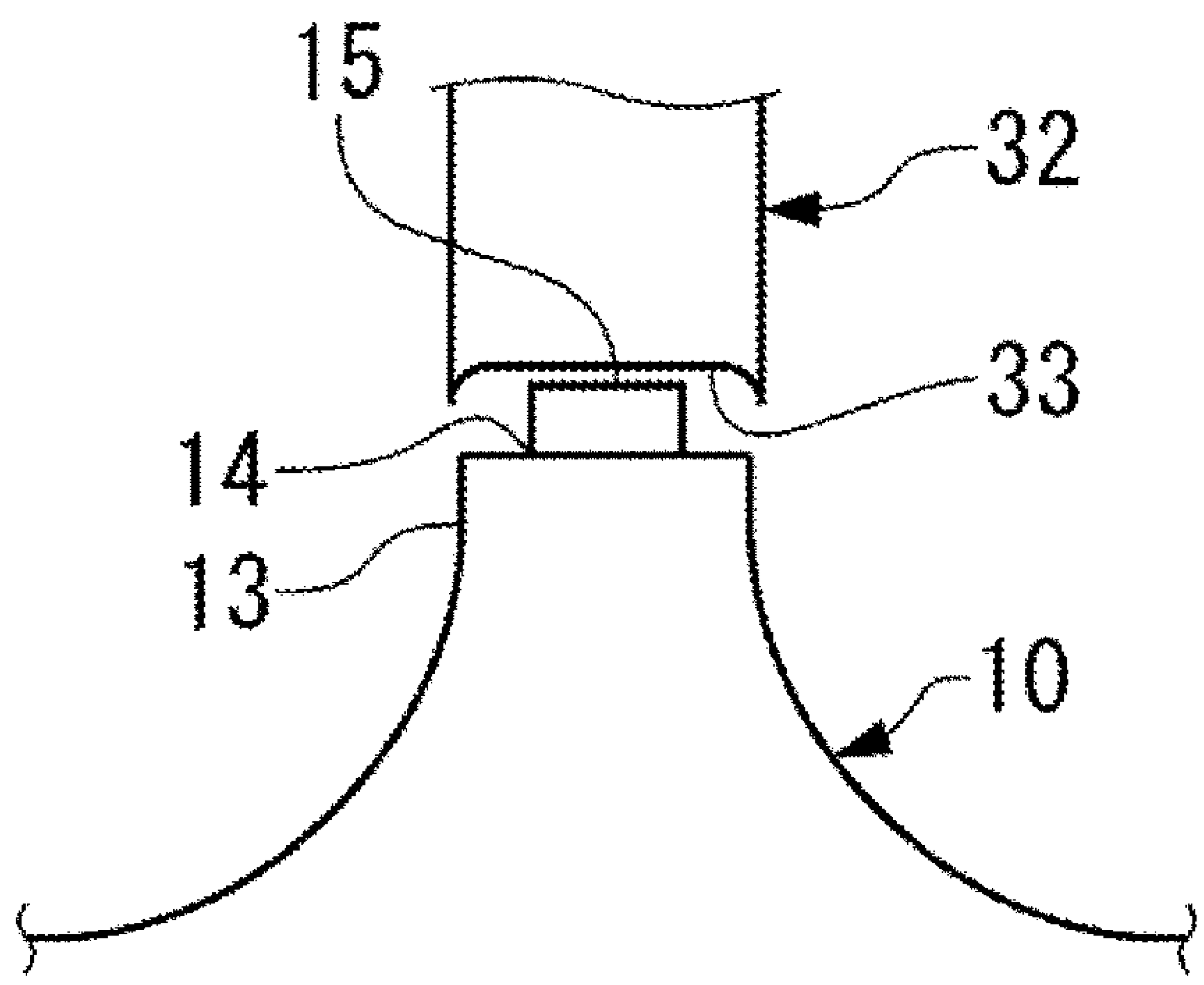


FIG. 4A

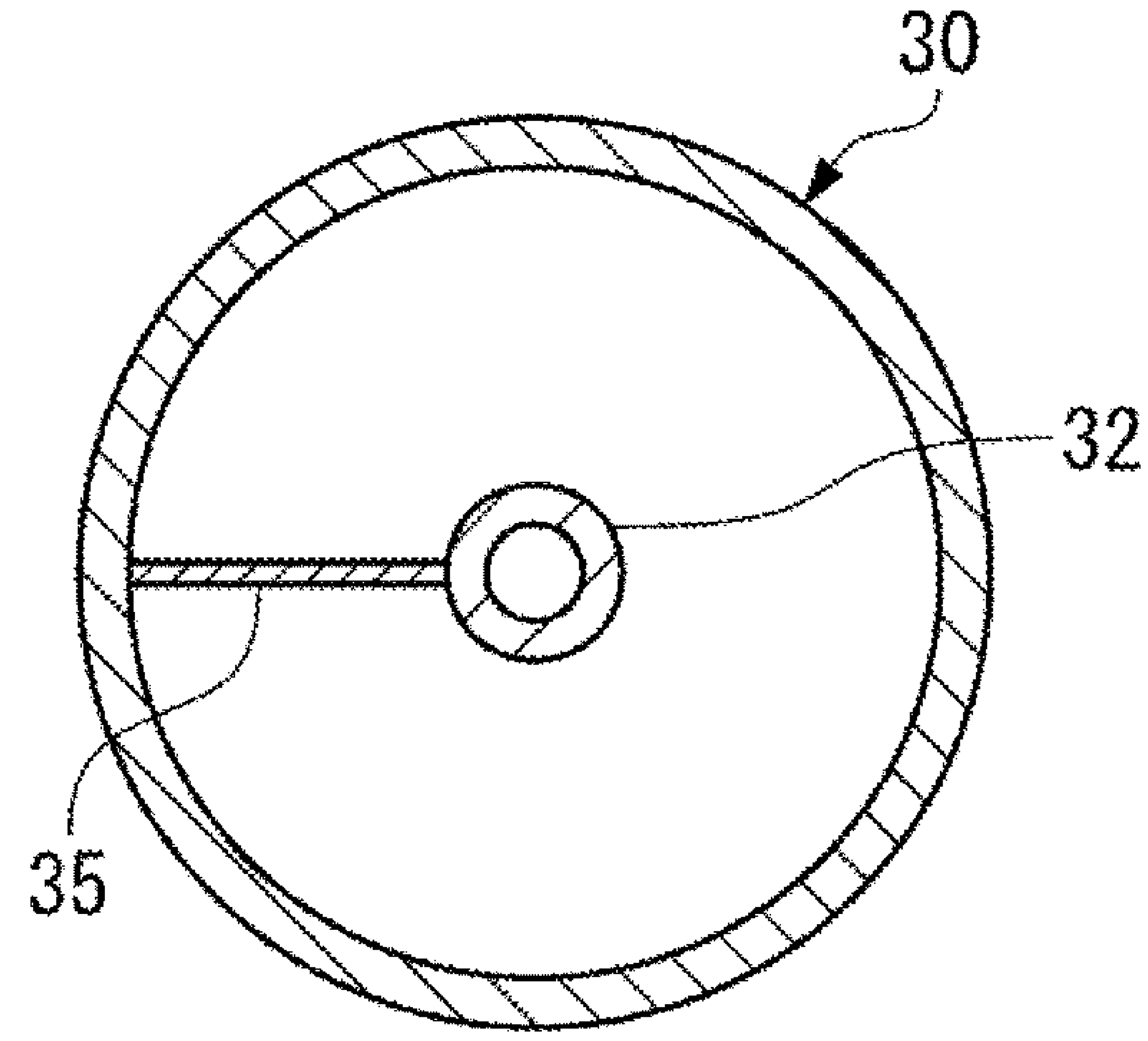


FIG. 4B

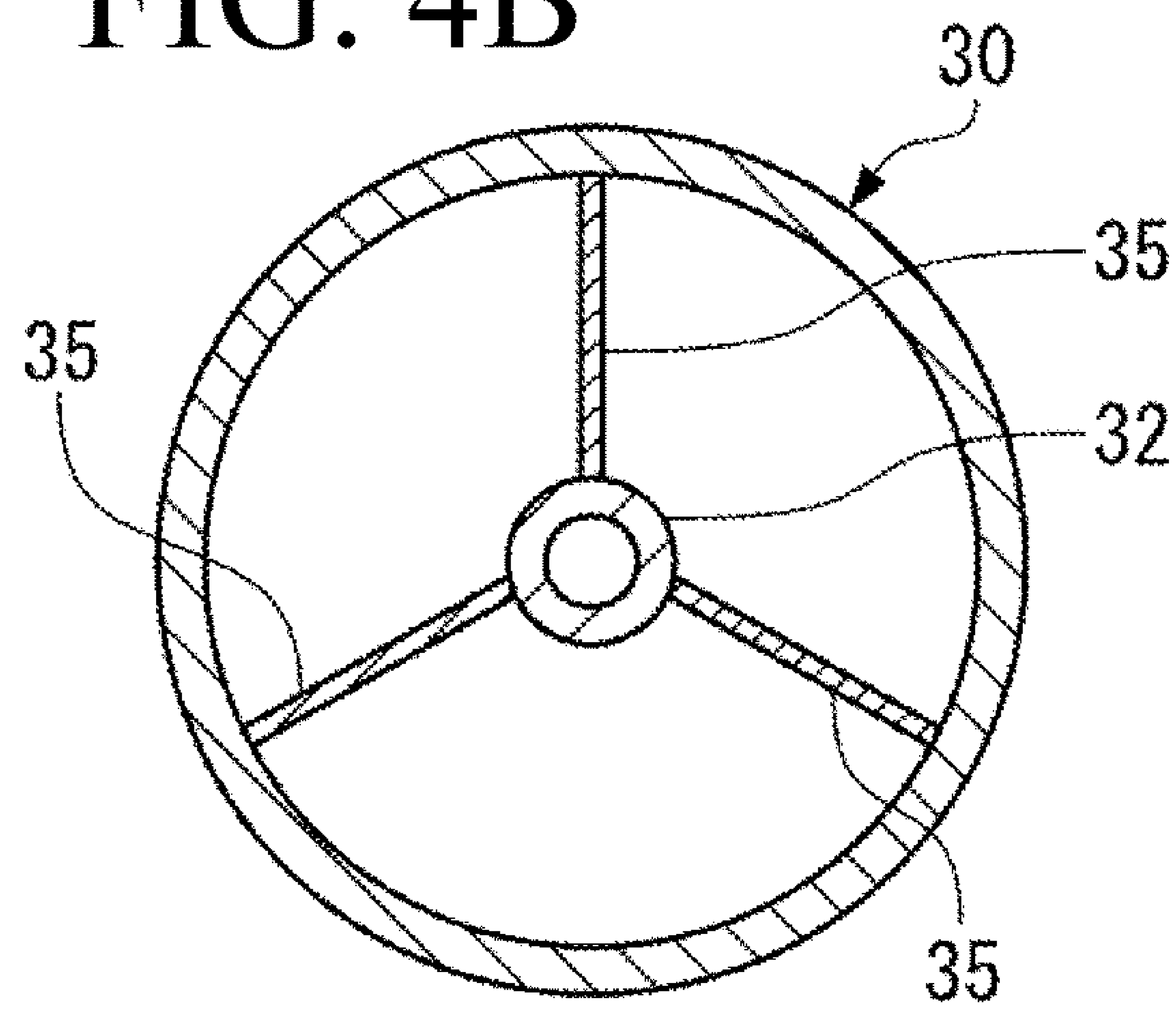


FIG. 4C

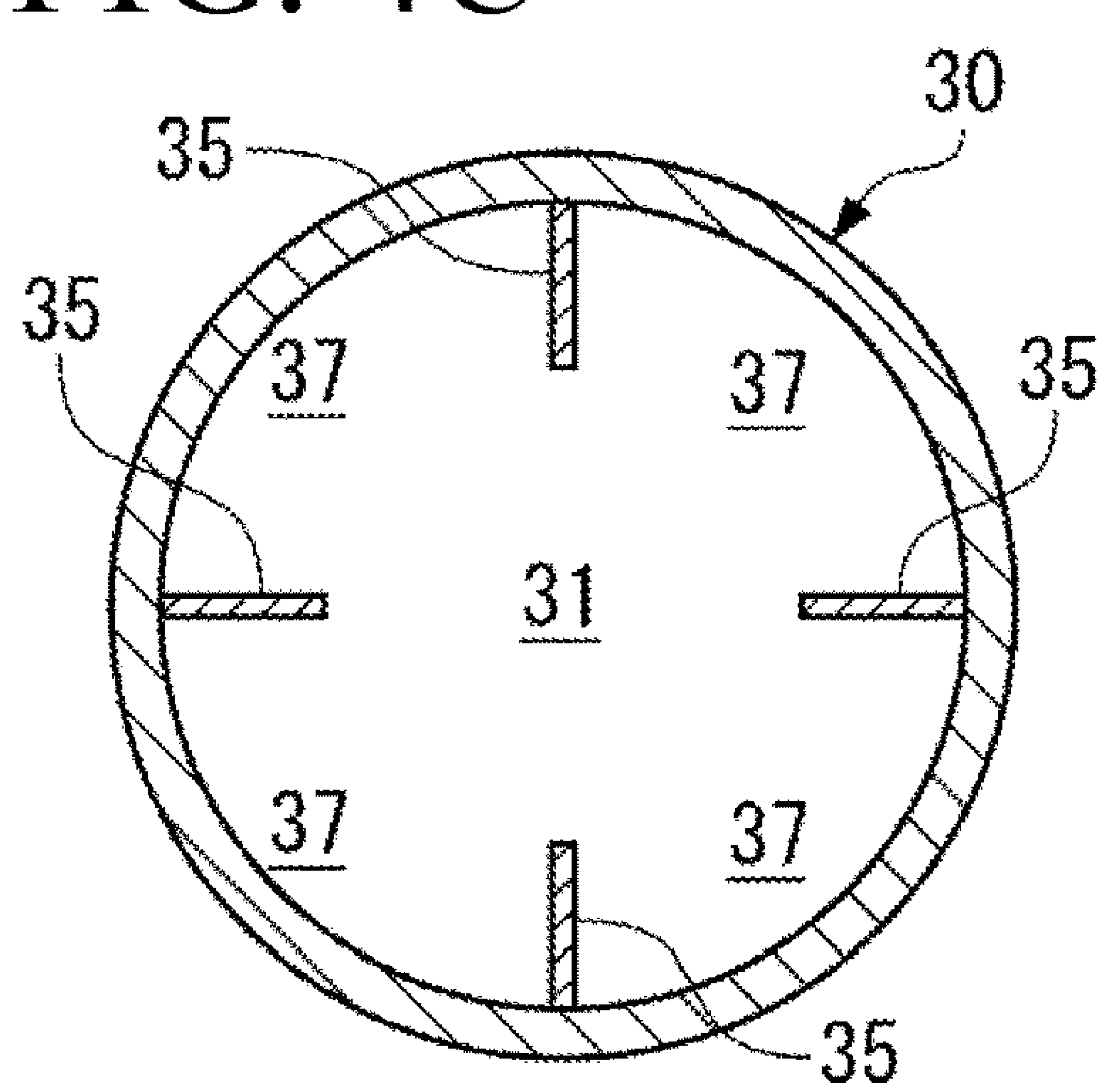
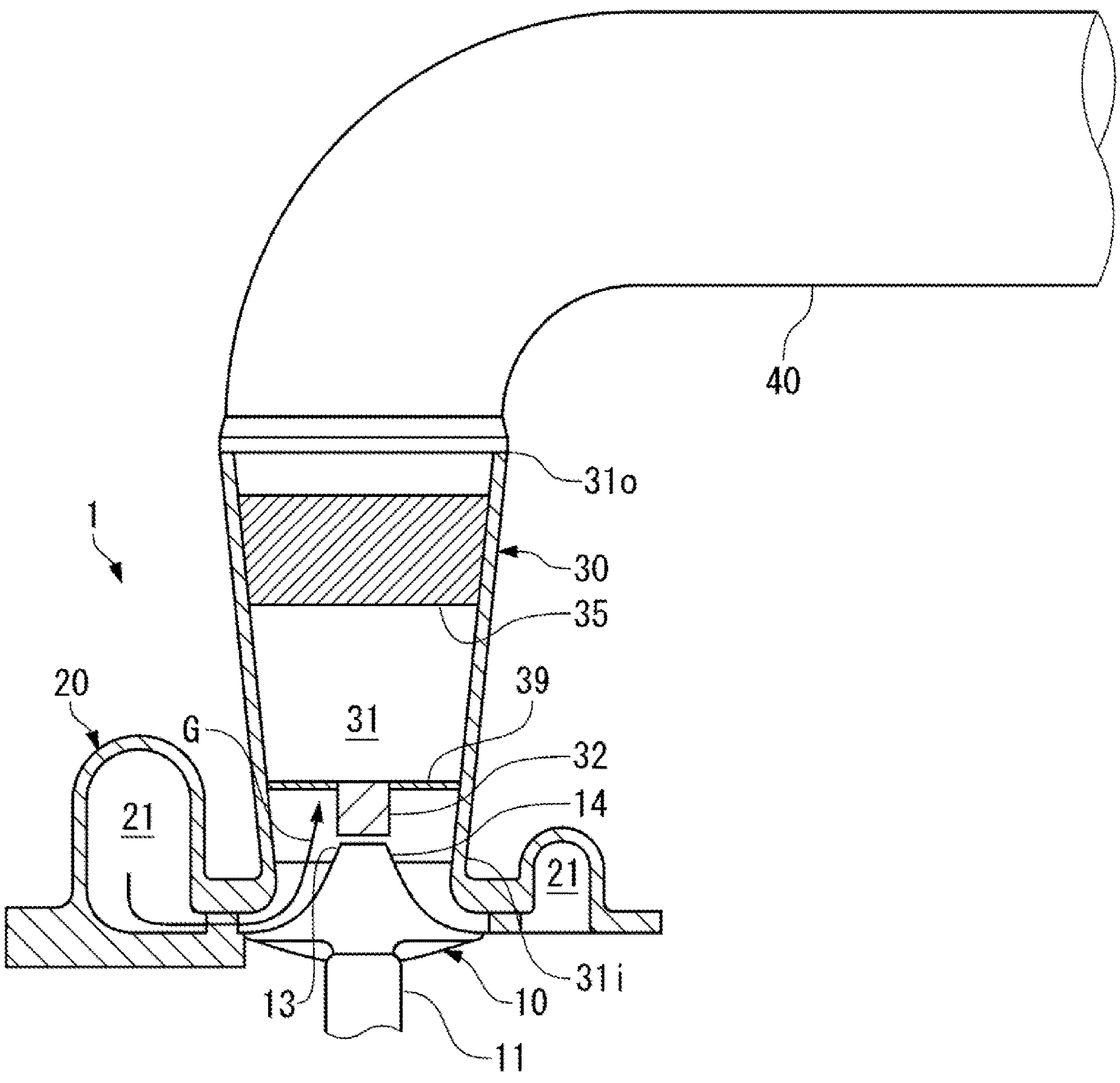


FIG. 5



GAS EXPANDER

TECHNICAL FIELD

The present invention relates to a technology for reducing vibration of a gas expander.

BACKGROUND

Various types of fluid machines, for example, a compressor for compressing a gas or an expander for expanding a gas instead have been used. The fluid machines generate vibration due to a flow of the compressed or expanded gas.

For example, Patent Literature 1 proposes providing a straightening vane for controlling a swirl flow of a compressed fluid in a discharge pipe connecting a centrifugal compression mechanism and a work apparatus provided downstream. Patent Literature 1 describes that providing the straightening vane controls the swirl flow of the fluid, and reduces vibration in an entire flow rate region from a low flow rate region to a high flow rate region.

PATENT LITERATURE

Patent Literature 1: JP 7-35091 A

SUMMARY

The straightening vane disclosed in Patent Literature 1 controls the swirl flow to exert a certain effect on reduction in vibration. However, the inventors have studied a gas expander, and found that there is still a room for improvement in reduction in vibration.

The gas expander and the centrifugal compression mechanism disclosed in Patent Literature 1 are similar in including a turbine wheel and a casing for housing the turbine wheel. However, in the gas expander, a gas having been expanded when passing through a swirl chamber flows through a turbine wheel to an outlet side, while in the centrifugal compressor, a gas having been compressed when passing through a swirl chamber flows through a turbine wheel to an outlet side. As such, a direction of a gas flow in the gas expander is reverse of that in the centrifugal compressor, and thus it is understood that only the straightening vane cannot sufficiently reduce vibration of the gas expander.

Accordingly, one or more embodiments of the present invention provide a gas expander with further reduced vibration.

A gas expander according to one or more embodiments of the present invention includes: a casing in which a swirl chamber is formed, a gas to be expanded passing through the swirl chamber; a turbine wheel that is housed in the casing and rotationally driven by the gas acting on the turbine wheel, the gas having passed through the swirl chamber; and a diffuser that stands on the casing in a direction of a rotating shaft of the turbine wheel, and has a flow path through which the gas having passed through the turbine wheel flows in the direction of the rotating shaft of the turbine wheel.

The gas expander according to one or more embodiments of the present invention includes: a swirl stopper that is provided in the diffuser and faces a downstream front end surface of a boss of the turbine wheel facing the flow path in the diffuser; and a swirl preventing plate that is provided in the diffuser and circumferentially partitions the flow path.

From the inventors' study, the gas having passed through the turbine wheel and reached the diffuser generates a swirl flow, and the downstream front end surface of the boss of the turbine wheel facing the flow path in the diffuser triggers the swirl flow to vibrate the rotating shaft of the turbine wheel. Thus, in the gas expander according to one or more embodiments of the present invention, the swirl stopper is provided to face the downstream front end surface of the boss of the turbine wheel, thereby preventing the downstream front end surface of the boss of the turbine wheel from triggering the swirl flow.

Also, the gas expander according to one or more embodiments of the present invention includes the swirl preventing plate that circumferentially partitions the flow path in the diffuser, thereby stopping the swirl flow even if generated.

The gas expander in one or more embodiments of the present invention refers to a gas expander including a turbine such as a radial turbine, a diagonal flow water turbine, or an axial turbine as a component.

According to one or more embodiments of the present invention, the swirl preventing plate is provided on a downstream side of the flow path in the diffuser, and in this case, the flow path in the diffuser includes a pressure recovery region on an upstream side and a swirl flow stopping region on the downstream side continuous with the pressure recovery region.

This can stop the swirl flow while ensuring a pressure recovery function of the diffuser.

According to one or more embodiments of the present invention, for the swirl preventing plate, $L31 \geq D10 \times 0.75$ is satisfied, or $L31 \geq D10 \times 1.2$ is satisfied, where D10 is a diameter of an inlet of the flow path in the diffuser, and L31 is a distance from the inlet to an end on the upstream side of the swirl preventing plate.

According to one or more embodiments of the present invention, in the diffuser, the swirl preventing plate is provided such that the end on the upstream side of the swirl preventing plate is away from the inlet to satisfy $A1 \times 1.6 \leq A2$, where A1 is a flow path area at the inlet of the flow path, and A2 is a flow path area at the end on the upstream side of the swirl preventing plate.

A swirl generated at an outlet of the turbine wheel is said to have a swirl length 1.0 to 1.5 times longer than D10. On the other hand, the swirl preventing plate provided to overlap the swirl has a great effect. However, the swirl preventing plate interfering with the swirl may cause pressure loss, which may prevent a sufficient pressure recovery function of the diffuser from being obtained. Thus, the distance L31 from the inlet to the end on the upstream side of the swirl preventing plate is ensured as described above to avoid the interference of the swirl preventing plate with the swirl as much as possible. Also, the pressure recovery function of the diffuser is obtained by the flow path area increasing from the upstream side toward the downstream side. Thus, a ratio above a certain level of the flow path area A2 at the end on the upstream side of the swirl preventing plate to the flow path area A1 at the inlet is ensured so as to be able to maintain a pressure recovery rate of the diffuser.

According to one or more embodiments of the present invention, for the swirl preventing plate, $L35 \geq D10 \times 0.45$ is satisfied, where L35 is an axial dimension of the swirl preventing plate, and D10 is a diameter of the inlet of the flow path in the diffuser.

This can sufficiently ensure a function of the swirl preventing plate.

According to one or more embodiments of the present invention, a plurality of swirl preventing plates radially partitions the flow path in the diffuser. This can sufficiently ensure a function of the swirl preventing plate.

According to one or more embodiments of the present invention, in a case where the swirl stopper includes a cylindrical member provided coaxially with the rotating shaft of the turbine wheel, $D32 \geq D13 \times 0.95$ is satisfied, or $1.2 \times D2 \geq D32 \geq D13 \times 0.95$ is satisfied, where D32 is a diameter of a portion of the swirl stopper facing the downstream front end surface of the boss of the turbine wheel, and D13 is a diameter of the downstream front end surface of the boss of the turbine wheel.

This can more effectively achieve a function of preventing the downstream front end surface of the boss of the turbine wheel from triggering the swirl flow.

According to one or more embodiments of the present invention, in the swirl stopper, a swirl stopping surface that faces the downstream front end surface of the boss of the turbine wheel has a peripheral edge protruding toward the downstream front end surface of the boss of the turbine wheel and an inner side recessed from the peripheral edge, and that the swirl stopper covers the downstream front end surface of the boss of the turbine wheel and an outer peripheral surface of the turbine wheel continuous with the downstream front end surface of the boss.

This can more effectively achieve a function of preventing the downstream front end surface of the boss of the turbine wheel from triggering the swirl flow.

According to one or more embodiments of the present invention, the swirl stopper is secured to the swirl preventing plate and the swirl preventing plate is secured to the diffuser, and thus the swirl stopper can be mounted to a predetermined position of the diffuser via the swirl preventing plate.

The swirl preventing plate is used to mount the swirl stopper to the diffuser. Thus, there is no need to prepare a separate special member for mounting the swirl stopper, and there is no need for a mounting operation using the member, thereby reducing cost including work burden.

According to one or more embodiments of the present invention, a plurality of, typically four, swirl preventing plates radially partition the flow path in the diffuser around the swirl stopper.

In the gas expander according to one or more embodiments of the present invention, the swirl stopper that faces the downstream front end surface of the boss of the turbine wheel is provided to prevent the downstream front end surface of the boss of the turbine wheel from triggering the swirl flow. Also, the gas expander according to one or more embodiments of the present invention includes the swirl preventing plate that circumferentially partitions the flow path in the diffuser, thereby stopping the swirl flow even if generated. From the above, One or more embodiments provide a gas expander with further reduced vibration.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1**A and FIG. **1**B each show a gas expander according to one or more embodiments of the present invention, FIG. **1**A is a vertical sectional view, and FIG. **1**B is a cross-sectional of a diffuser shown in FIG. **1**A.

FIG. **2** shows dimensions of elements of the gas expander according to one or more embodiments.

FIG. **3** shows examples of shapes of a swirl stopping cylinder of the gas expander according to one or more embodiments.

FIG. **4** shows examples of shapes of a swirl preventing plate of the gas expander according to one or more embodiments.

FIG. **5** shows a variant of the gas expander according to one or more embodiments.

DETAILED DESCRIPTION

Now, a fluid machine according to one or more embodiments of the present invention will be described taking a gas expander **1** as an example.

The gas expander **1** is used for sucking and expanding a high pressure gas discharged from, for example, a plant (process) side (hereinafter referred to as a process gas) to convert pressure energy of the gas into speed energy (mechanical energy) to recover power and reduce power of a power source, for example, a drive motor.

As shown in FIG. **1**, the gas expander **1** includes a turbine wheel **10** that receives a process gas G and rotates, and a rotating shaft **11***a* that rotates integrally with the turbine wheel **10**. The rotating shaft **11** is coupled to the power source.

The gas expander **1** includes a casing **20** for housing the turbine wheel **10** therein.

The casing **20** includes a swirl chamber **21** continuous with a suction port (not shown) for introducing the process gas G, and the turbine wheel **10** receives energy of the process gas G having passed through the swirl chamber **21** and is rotationally driven.

The gas expander **1** includes a diffuser **30** into which the process gas G having passed through the turbine wheel is discharged. The diffuser **30** is mounted to the casing **20** in a direction of the rotating shaft **11** of the turbine wheel **10** and coaxially with the rotating shaft **11**. The process gas G having passed through the turbine wheel **10** is recovered in dynamic pressure while passing through the diffuser **30**, and then discharged into a pipe **40** connecting to the diffuser **30**. With reference to a direction of a flow of the process gas G in the gas expander **1**, upstream and downstream directions are defined.

The diffuser **30** has an opening area gradually increasing from an inlet **31***i* of a flow path **31** continuous with an inside of the casing **20** toward an outlet **31***o*, thereby reducing a flow speed of the passing process gas G to increase and recover pressure.

The diffuser **30** may have any shape such as a conical shape or a semi-spindle shape as long as the diffuser **30** achieves its function.

When the process gas G is discharged into the diffuser **30**, a swirl flow is sometimes formed in a certain operation region. If an exciting force caused by the swirl flow exceeds attenuation performance of the turbine wheel **10**, the rotating shaft **11** continuous with the turbine wheel **10** is vibrated. The inventors checked distribution of pressure (static pressure) caused by the process gas G at the inlet **31***i* of the diffuser **30**, and differential pressure is created between a center and an outer peripheral side of the diffuser **30** in a certain operation region. The turbine wheel **10** faces the flow path **31** in the diffuser **30**, and with high differential pressure, the differential pressure caused by the swirl flow is applied to the entire turbine wheel **10** from the downstream front end surface **14** of the boss **13** of turbine wheel **10**. Thus, a circumferential force acts on the rotating shaft **11**, and whirling of a direction of the force causes shaft vibration.

The vibration of the rotating shaft **11** may be generated in a partial load operation. Specifically, at a start on the process side, in the partial load operation in which a rated operation is not achieved, the process gas G that does not reach a rated temperature is supplied to the gas expander **1**, and a phenomenon of generation of the shaft vibration is observed during an increase in temperature from a temperature at the start to the rated temperature.

At a partial load, a volume flow rate is lower than that near a rated load, which may reduce a flow speed in a blade angle direction at the outlet of the gas from the turbine wheel **10** and increase vibration on a swirl flow side.

In order to prevent or reduce vibration caused by a swirl flow, as shown in FIG. **1**, in the gas expander **1** according to one or more embodiments, a swirl stopping cylinder (swirl stopper) **32** and a swirl preventing plate **35** are provided in the diffuser **30**. The swirl stopping cylinder **32** and the swirl preventing plate **35** will be described below.

The swirl stopping cylinder **32** is a hollow cylindrical member having a swirl stopping surface **33** as an upstream front end surface and a rear end surface **34**, and is provided coaxially with the rotating shaft **11** of the turbine wheel **10**. Although an example of using a hollow member is shown here, a solid, that is, a column member may be used, and the cylinder in one or more embodiments of the present invention has a concept including a column. Although an example of the cylinder is shown here, one or more embodiments of the present invention may adopt other shapes such as a rectangular cylinder, a conical shape, or a semi-spindle shape.

The swirl stopping surface **33** of the swirl stopping cylinder **32** is closed. The swirl stopping surface **33** is provided to face the downstream front end surface **14** of the boss **13** of the turbine wheel **10** with a minute gap therebetween, and the downstream front end surface **14** of the boss **13** is covered with the swirl stopping cylinder **32**. Thus, an air flow is prevented from entering between the downstream front end surface **14** of the boss **13** and the swirl stopping surface **33** of the swirl stopping cylinder **32**.

A generated swirl is triggered by a wall surface. For the turbine wheel **10**, the swirl generated after passing through the turbine wheel **10** is triggered by the downstream front end surface **14** of the boss **13**. Thus, the downstream front end surface **14** is not exposed to the flow path of the process gas G, thereby preventing generation of the swirl at the downstream front end surface **14** or preventing the generated swirl from affecting the downstream front end surface **14**.

The swirl stopping cylinder **32** can achieve its function when located only near the downstream front end surface **14** of the boss **13**. However, in one or more embodiments, in order to hold the swirl stopping cylinder **32** via the swirl preventing plate **35** in a predetermined position of the diffuser **30**, the swirl stopping cylinder **32** is extended to an upstream side of the diffuser **30**.

Next, the swirl preventing plates **35** circumferentially partition an inside of the diffuser **30** into four flow paths **37**. Specifically, in one or more embodiments, the four swirl preventing plates **35** are prepared and radially placed around the swirl stopping cylinder **32**.

Each swirl preventing plate **35** has a trapezoidal planar shape along an increasing opening diameter of the diffuser **30**. For each swirl preventing plate **35**, an outer end in a radial direction of the diffuser **30** is joined to an inner peripheral surface of the diffuser **30**, and an inner end is joined to the swirl stopping cylinder **32**. With this configuration, the swirl stopping cylinder **32** is held in a predetermined position of the diffuser **30**.

As described above, in one or more embodiments, the swirl preventing plates **35** are provided to form the four partitioned flow paths **37** on the downstream side of the diffuser **30**. Thus, the process gas G having passed through the flow path **31** on the upstream side forms a swirl flow, but when the swirl flow reaches the flow paths **37** independent of each other in a region in which the swirl preventing plates **35** are provided, the swirl preventing plates **35** impede and stop the swirl flow, thereby preventing generation of a swirl.

As such, the diffuser **30** according to one or more embodiments includes a pressure recovery region formed of the flow path **31** on the upstream side and a swirl flow stopping region formed of the flow paths **37** on the downstream side continuous with the pressure recovery region.

Next, with reference to FIG. **2**, examples of the swirl stopping cylinder **32** and the swirl preventing plate **35** in the gas expander **1** will be described.

First, a diameter D32 of a portion of the swirl stopping cylinder **32** facing the downstream front end surface **14** of the turbine wheel **10** and a diameter D13 of the downstream front end surface **14** of the boss **13** of the turbine wheel **10** are required to have the following relationship because the swirl stopping cylinder **32** is provided to cover the downstream front end surface **14** of the boss **13** as much as possible so as not to be exposed:

$$D32 \geq D13 \times 0.95 \qquad \text{Expression (1)}$$

However, the following relationship prevents the swirl stopping cylinder **32** from resisting the process gas G flowing through the turbine wheel **10** into the diffuser **30** and inhibiting a smooth flow of the process gas G:

$$D13 \times 1.2 \geq D32 \geq D13 \times 0.95 \qquad \text{Expression(2)}$$

The above relationships assume that the swirl stopping cylinder **32** and the turbine wheel **10** are placed coaxially with each other, however, in one or more present inventions, the swirl stopping cylinder **32** and the turbine wheel **10** may be decentered. In this case, the entire downstream front end surface **14** may be included in a range of a projection surface of the swirl stopping surface **33**, and it is necessary that at least an area A33 of the swirl stopping surface **33** of the swirl stopping cylinder **32** is larger than an area A14 of the downstream front end surface **14** of the boss **13**.

Also, an example in which the swirl stopping cylinder **32** has an axially uniform diameter D32 is shown here, however, any diameter may be adopted unless the function of the diffuser **30** is inhibited of a gradually increasing opening area reducing the flow speed of the passing process gas G and increasing and recovering the pressure. For example, the diameter may increase from the downstream front end surface **14** toward the upper end, or vice versa.

Next, a gap L33 between the swirl stopping surface **33** of the swirl stopping cylinder **32** and the downstream front end surface **14** of the boss **13** is as narrow as possible based on the function of the swirl stopping cylinder **32**. However, interference of the swirl stopping cylinder **32** with the boss **13** due to whirling of the boss **13** caused by the rotation of the turbine wheel **10** or thermal expansion of the turbine wheel **10** should be avoided. Thus, in one or more embodiments, depending on the dimension of the gas expander **1**, the gap L33 is 5 to 30 mm, 5 to 20 mm, or 5 to 15 mm.

Next, the shape of the swirl stopping surface **33** of the swirl stopping cylinder **32** will be described.

The swirl stopping cylinder **32** covers the downstream front end surface **14** of the boss **13**. As shown in FIG. **3**A, the swirl stopping cylinder **32** can achieve its function even if the swirl stopping surface **33** has a flat surface. However, as shown in FIG. **3**B, the swirl stopping surface **33** is shaped so that a peripheral edge protrudes while an inner side thereof is recessed. Then, the swirl stopping cylinder **32** can cover not only the downstream front end surface **14** but also the outer peripheral surface of the boss **13** continuous with the downstream front end surface **14**, thereby further reducing an exciting force applied on the rotating shaft **11** of the turbine wheel **10**. Also, as shown in FIG. **3**C, in a case where a nut **15** for securing the turbine wheel **10** is provided on the downstream front end surface **14** of the boss **13**, the swirl stopping surface **33** is shaped so that the inner side is recessed so as to be able to cover the downstream front end surface **14** including the nut **15**.

Next, with reference to FIG. **2**, examples of the swirl preventing plate **35** will be described.

First, a position where the swirl preventing plate **35** is provided will be described.

The swirl preventing plate **35** partitions the flow path **31** in the diffuser **30** into the flow paths **37** to stop a swirl flow, and may be provided in any position of the diffuser **30** with consideration only for the function of the swirl preventing plate **35**. However, it is difficult to achieve the function of the diffuser **30** of recovering pressure in the narrow flow paths **37** partitioned by the swirl preventing plates **35**. Also, a swirl generated at the outlet of the turbine wheel **10** is said to have a swirl length 1.0 to 1.5 times longer than D10. On the other hand, the swirl preventing plate provided at a position where the swirl occurs has a great effect. However, the swirl preventing plate **35** interfering with the swirl may cause pressure loss, which may prevent a sufficient pressure recovery function of the diffuser **30** from being obtained. Thus, in one or more embodiments, the swirl preventing plate **35** is provided on the downstream side in the diffuser **30** to ensure the pressure recovery function of the diffuser **30**. Specifically, the following Expression (3) is satisfied or the following Expression (4) is satisfied, where D10 is a diameter of the inlet **31***i* of the flow path **31** in the diffuser **30**, and L31 is a distance from the inlet **31***i* to an end **38** on the upstream side of the swirl preventing plate **35**:

$$L31 \geq D10 \times 0.75 \qquad (3)$$

$$L31 \geq D10 \times 1.2 \qquad (4)$$

Also, the pressure recovery function of the diffuser **30** is obtained by the flow path area increasing from the upstream side toward the downstream side. Thus, in one or more embodiments, as shown in FIG. **2**, the swirl preventing plate **35** is placed such that the end **38** on the upstream side of the swirl preventing plate **35** is away from the inlet **31***i* to satisfy the following Expression (5), where A1 is a flow path area at the inlet **31***i* of the flow path **31**, and A2 is a flow path area at the end **38** on the upstream side of the swirl preventing plate **35**. A ratio above a certain level of the flow path area A2 at the end **38** on the upstream side of the swirl preventing plate **35** to the flow path area A1 at the inlet is ensured to maintain a pressure recovery rate of the diffuser **30**. The flow path area A1 and the flow path area A2 are specified except a portion occupied by the swirl stopping cylinder **32**.

$$A1 \times 1.6 \leq A2 \qquad (5)$$

Next, for an axial dimension (length) L35 of the swirl preventing plate **35**, it satisfies the following Expression (6).

$$L35 \geq D10 \times 0.45 \qquad (6)$$

Next, for the number of the swirl preventing plates **35** provided, the four swirl preventing plates **35** are provided in the embodiments described above. This is because the four swirl preventing plates **35** having the same dimension are radially placed at regular intervals to facilitate positioning of the swirl stopping cylinder **32** coaxially with the rotating shaft **11**, that is, at the center of the flow path **31** in the diffuser **30**.

The function of the swirl preventing plate **35** of stopping the swirl flow is not only achieved by the four swirl preventing plates **35**, but as shown in FIGS. **4**A and **4**B, a single (one) swirl preventing plate **35** or three swirl preventing plates **35** may be provided, or more than four swirl preventing plates **35** may be provided. Also, as shown in FIG. **4**C, the swirl preventing plates **35** may protrude from the inner peripheral surface of the diffuser **30** to a predetermined radial range.

The swirl preventing plate **35** described above is provided in parallel with an axial direction, but not limited to this, the swirl preventing plate **35** may be tilted with respect to the axial direction. Further, the swirl preventing plate **35** has a flat surface, but not limited to this, may have a curved surface.

As described above, in the gas expander **1** according to one or more embodiments, the swirl stopping cylinder **32** that faces the downstream front end surface **14** of the turbine wheel **10** is provided to prevent the downstream front end surface **14** of the turbine wheel **10** from triggering the swirl flow. Also, the gas expander **1** includes the swirl preventing plate that circumferentially partitions the flow path **31** in the diffuser, thereby stopping the swirl flow even if generated. From the above, one or more embodiments can provide a gas expander **1** with further reduced vibration.

Also, in the gas expander **1** according to one or more embodiments, the swirl stopping cylinder **32** is secured to the swirl preventing plate **35**, the swirl preventing plate **35** is secured to the diffuser **30**, and thus the swirl stopping cylinder **32** is mounted to a predetermined position of the diffuser **30** via the swirl preventing plate **35**. The swirl preventing plate **35** is used to mount the swirl stopping cylinder **32** to the diffuser **30**. Thus, there is no need to prepare a separate special member for mounting the swirl stopping cylinder **32**, and there is no need for a mounting operation using the member, thereby reducing cost including work burden.

In the gas expander **1** according to one or more embodiments, the flow path **31** in the diffuser **30** includes the pressure recovery region on the upstream side and the swirl flow stopping region on the downstream side continuous with the pressure recovery region. This can stop the swirl flow while ensuring the pressure recovery function of the diffuser **30**. The swirl flow stopping region radially partitions the flow path in the diffuser **30**, thereby sufficiently ensuring the function of the swirl preventing plate **35**.

Embodiments of the present invention have been described. The components listed in the embodiments may be chosen or changed to other components without departing from the gist of the present invention.

For example, in the gas expander **1** described above, the swirl stopping cylinder **32** is supported in the diffuser **30** via the swirl preventing plate **35**. However, as shown in FIG. **5**, for example, the swirl stopping cylinder **32** may be supported in the diffuser **30** using a rod-like support **39** independently of the swirl preventing plate **35**. In this case, the swirl preventing plate **35** radially partitions the flow path **31** in the diffuser **30** without via the swirl stopping cylinder **32**.

REFERENCE SIGNS LIST

1 gas expander
10 turbine wheel
11 rotating shaft
13 boss
14 front end surface
15 nut

20 casing
21 swirl chamber
30 diffuser
31 flow path
31*i* inlet
31*o* outlet
32 swirl stopping cylinder
33 swirl stopping surface
34 rear end surface
35 swirl preventing plate
37 flow path
38 end
39 support
40 pipe
G process gas

Although the disclosure has been described with respect to only a limited number of embodiments, those skilled in the art, having benefit of this disclosure, will appreciate that various other embodiments may be devised without departing from the scope of the present invention. Accordingly, the scope of the invention should be limited only by the attached claims.

The invention claimed is:

1. A gas expander comprising:
a casing where a swirl chamber is formed, wherein a gas to be expanded passes through the swirl chamber;
a turbine wheel that is housed in the casing and rotationally driven by the gas, wherein the gas that rotationally drives the turbine wheel has passed through the swirl chamber and expanded;
a diffuser that:
is mounted to the casing in a direction of a rotating shaft of the turbine wheel, and
includes a flow path where the gas, having passed through the turbine wheel, flows in the direction of the rotating shaft,
a swirl stopper that:
is disposed in the diffuser,
faces a downstream front end surface of a boss of the turbine wheel that faces the flow path, and
includes a closed swirl stopping surface that is disposed to face the downstream front end surface of the boss with a gap between the closed swirl stopping surface and the downstream front end surface; and
a swirl preventing plate that circumferentially partitions the flow path,
wherein $L31 \geq D10 \geq 0.75$ is satisfied, where D10 is a diameter of an inlet of the flow path and L31 is a distance from the inlet to an end on the upstream side of the swirl preventing plate.

2. The gas expander according to claim **1**, wherein:
the swirl preventing plate is provided on a downstream side of the flow path,
the flow path includes:
a pressure recovery region on an upstream side, and
a swirl flow stopping region on the downstream side continuous with the pressure recovery region.

3. The gas expander according to claim **2**, wherein $L31 \geq D10 \times 0.75$ is satisfied, where D10 is a diameter of an inlet of the flow path and L31 is a distance from the inlet to an end on the upstream side of the swirl preventing plate.

4. The gas expander according to claim **2**, wherein $L31 \geq D10 \times 1.2$ is satisfied, where D10 is a diameter of an inlet of the flow path and L31 is a distance from the inlet to an end on the upstream side of the swirl preventing plate.

5. The gas expander according to claim **2**, wherein:
in the diffuser, a flow path area increases from the upstream side toward the downstream side,
the swirl preventing plate is disposed so that the end on the upstream side of the swirl preventing plate is away from the inlet, and
$A1 \times 1.6 \leq A2$ is satisfied, where A1 is the flow path area at the inlet of the flow path and A2 is the flow path area at the end on the upstream side of the swirl preventing plate.

6. The gas expander according to claim **2**, wherein $L35 \geq D10 \times 0.45$ is satisfied, where L35 is an axial dimension of the swirl preventing plate and D10 is a diameter of the inlet of the flow path.

7. The gas expander according to claim **1**, wherein $L31 \geq D10 \times 1.2$ is satisfied, where D10 is a diameter of an inlet of the flow path and L31 is a distance from the inlet to an end on the upstream side of the swirl preventing plate.

8. The gas expander according to claim **1**, wherein:
in the diffuser, a flow path area increases from the upstream side toward the downstream side,
the swirl preventing plate is disposed so that the end on the upstream side of the swirl preventing plate is away from the inlet, and $A1 \times 1.6 \leq A2$ is satisfied, where A1 is the flow path area at the inlet of the flow path and A2 is the flow path area at the end on the upstream side of the swirl preventing plate.

9. The gas expander according to claim **1**, wherein:
the gas expander includes a plurality of swirl preventing plates, and the plurality of swirl preventing plates radially partition the flow path.

10. The gas expander according to claim **1**, wherein:
the swirl stopper includes a cylindrical member disposed coaxially with the rotating shaft of the turbine wheel, and $D32 \geq D13 \times 0.95$ is satisfied, where D32 is a diameter of the closed swirl stopping surface of the swirl stopper and D13 is a diameter of the downstream front end surface of the boss of the turbine wheel.

11. The gas expander according to claim **10**, wherein $D13 \times 1.2 \geq D32 \geq D13 \times 0.95$ is satisfied.

12. The gas expander according to claim **1**, wherein:
the swirl stopper is secured to the swirl preventing plate and the swirl preventing plate is secured to the diffuser, and
the swirl stopper is mounted to a predetermined position of the diffuser via the swirl preventing plate.

13. The gas expander according to claim **12**, wherein:
the gas expander includes a plurality of swirl preventing plates, and
the plurality of the swirl preventing plates radially partition the flow path in the diffuser around the swirl stopper.

14. The gas expander according to claim **1**, wherein:
the gas expander further includes a plurality of swirl preventing plates, and
the plurality of swirl preventing plates radially partition the flow path.

15. A gas expander comprising:
a casing where a swirl chamber is formed, wherein a gas to be expanded passes through the swirl chamber;
a turbine wheel that is housed in the casing and rotationally driven by the gas, wherein the gas that rotationally drives the turbine wheel has passed through the swirl chamber and expanded;
a diffuser that:
is mounted to the casing in a direction of a rotating shaft of the turbine wheel, and includes a flow path

where the gas, having passed through the turbine wheel, flows in the direction of the rotating shaft,

a swirl stopper that:

is disposed in the diffuser,

faces a downstream front end surface of a boss of the turbine wheel that faces the flow path, and

includes a closed swirl stopping surface that is disposed to face the downstream front end surface of the boss with a gap between the closed swirl stopping surface and the downstream front end surface; and

a swirl preventing plate that circumferentially partitions the flow path,

wherein $L35 \geq D10 \times 0.45$ is satisfied, where L35 is an axial dimension of the swirl preventing plate and D10 is a diameter of the inlet of the flow path.

16. A gas expander comprising:

a casing where a swirl chamber is formed, wherein a gas to be expanded passes through the swirl chamber;

a turbine wheel that is housed in the casing and rotationally driven by the gas, wherein the gas that rotationally drives the turbine wheel has passed through the swirl chamber and expanded;

a diffuser that:

is mounted to the casing in a direction of a rotating shaft of the turbine wheel, and includes a flow path where the gas, having passed through the turbine wheel, flows in the direction of the rotating shaft,

a swirl stopper that:

is disposed in the diffuser,

faces a downstream front end surface of a boss of the turbine wheel that faces the flow path, and

includes a closed swirl stopping surface that is disposed to face the downstream front end surface of the boss with a gap between the closed swirl stopping surface and the downstream front end surface; and

a swirl preventing plate that circumferentially partitions the flow path, wherein in the swirl stopper, the closed swirl stopping surface has a protruding peripheral edge and an inner side recessed from the peripheral edge, and

the swirl stopper covers the downstream front end surface of the boss and an outer peripheral surface of the turbine wheel continuous with the downstream front end surface of the boss.

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